Translation of the application
document as originally filed

Determination of a specific immunoglobulin using multiple antigens

DESCRIPTION

The present invention concerns a method for the determination of a specific immunoglobulin using antigens that comprise several epitope regions.

The detection of immunoglobulins in body fluids, in particular in human sera, is used to diagnose infections with microorganisms, in particular viruses, such as HIV, hepatitis viruses etc. The presence of specific immunoglobulins in the examined sample is usually detected by reaction with one or several antigens that react with the specific immunoglobulins. Methods for the determination of specific immunoglobulins in the sample liquid must be sensitive, reliable, simple and rapid.

In recent years more and more detection systems based on non-radioactive marker groups have been developed in which the presence of an analyte, e.g. a specific antibody, in the examined sample can be determined with the aid of optical (e.g. luminescence or fluorescence), NMR-active or metal-precipitating detection systems.

EP-A-0 307 149 discloses an immunological test for an antibody in which two recombinant polypeptides are used as antigens one of which is immobilized on a solid phase and the other carries a marker group and both recombinant antigens are expressed in different

organisms to increase the specificity of the test.

EP-A-0 366 673 discloses a method for the detection of antibodies in a sample in which an antibody is detected by reaction with a purified labelled antigen and with the same purified antigen in a solid phase-bound form. Human IgG is for example disclosed as an antigen.

EP-A-0 386 713 describes a method for the detection of antibodies against HIV using two solid supports in which various HIV antigens are immobilized on the two solid supports each of which is brought into contact with an aliquot of a sample and with a labelled HIV antigen wherein the presence of antibodies is detected by a positive reaction in at least one of the tests. Recombinantly produced polypeptides are disclosed as HIV antigens.

EP-A-0 507 586 describes a method for carrying out an immunological test for a specific immunoglobulin in which a sample is brought into contact with two antigens capable of binding the immunoglobulin, wherein the first antigen carries a group suitable for binding to a solid support and the second antigen carries a marker group. The marker group can be a direct marker group e.g. an enzyme, a chromogen, a metal particle, or also an indirect marker group i.e. the marker group attached to the antigen can react with a receptor for the marker group which in turn carries a signal-generating group. A fluorescein derivative is mentioned as an example of such an indirect marker group, the receptor of which is an antibody which in turn is coupled to an enzyme. Polypeptides such as the hepatitis B surface antigen are disclosed as antigens. SH groups are introduced into

this antigen by derivatization which are used to couple the fluorescein.

EP-A-0 507 587 discloses a specific method for the detection of IgM antibodies in which the sample is incubated with a labelled antigen which is directed against the antibody to be detected and with a second antibody which is also directed against the antibody to be detected and is capable of binding to a solid phase.

However, the immunological methods of detection according to the bridge test concept which are known from the state of the art in which a labelled antigen and an antigen capable of binding to a solid phase are used, still have major weaknesses. In particular they have a low sensitivity when a relatively low affinity is present between the antibody to be determined and the antigen. This is especially the case for a seroconversion that has occurred only recently and/or when new subtypes of the infectious microorganism occur. A further disadvantage of the previously known bridge test concepts is the risk of a false negative evaluation of high-titre samples due to the Hook effect.

The object of the present invention was therefore to provide a method for the detection of specific antibodies in which the disadvantages of the state of the art are at least partially eliminated and which has an adequate sensitivity especially in the case of a seroconversion which has only recently occurred and in the case of new microorganism subtypes. In addition the method according to the invention is intended to reduce the Hook effect.

This object is achieved by a method for the immunological determination of a specific antibody in a sample liquid in which the sample liquid is incubated in the presence of a solid phase with two antigens directed against the antibody to be determined in which the first antigen carries at least one marker group and the second antigen is (a) bound to the solid phase or (b) is present in a form capable of binding to the solid phase and the antibody to be determined is detected by determining the marker group in the solid phase or/and in the liquid phase characterized in that at least one of the two antigens comprises several epitope regions which react with the antibody to be determined.

Surprisingly it was found in bridge test immunoassays that the sensitivity of the test, especially for sera containing antibodies which have a low affinity for the antigen used, is improved by using at least one multimeric antigen i.e. an antigen with multiple epitope regions. In addition the method according to the invention leads to a considerable reduction of the risk of false negative evaluations of high-titre samples due to the Hook effect. The optimization of the antigen presentation by increasing the epitope density in the bridge test concept generally leads to an improvement in the reactivity with specific immunoglobulins in polyclonal sera as they occur in a sample liquid such as e.g. serum. A further advantage of the method according to the invention is that multimeric antigens have a considerably improved stability compared to monomeric antigens.

Two antigens are used in a method for the immunological determination of a specific antibody according to the bridge test concept. In a first preferred embodiment of

the method according to the invention a multimeric antigen is used as the labelled antigen and a monomeric antigen is used as the solid phase antigen. In a second embodiment of the method according to the invention a multimeric antigen can be used as the solid phase antigen and a monomeric antigen can be used as the labelled antigen. In a third preferred embodiment multimeric antigens can be used as the labelled antigen and as the solid phase antigen.

The multimeric antigens contain multiple epitope regions i.e. structures, preferably peptide or polypeptide sequences, that react immunologically with the antibody to be determined. The epitope regions are preferably linked together via immunologically inactive regions e.g. via spacer regions. Multimeric antigens are preferably used which comprise several identical epitope regions.

The multimeric antigens according to the invention preferably contain more than 1 to 80 immunologically reactive epitope regions and particularly preferably more than 1 to 40 epitope regions. The epitope regions can be coupled to a high molecular carrier or linked together directly or via spacer regions.

The epitope regions are preferably immunologically reactive synthetic peptide sequences having a length of 6 to 50 amino acids or recombinant polypeptide sequences having a length of preferably up to 1000 amino acids. In addition to the actual epitope regions synthetic peptide epitopes preferably also contain a spacer region which for example can be used for coupling to other epitopes or to a carrier or/and for coupling marker groups or

solid phase binding groups.

The spacer region is preferably an immunologically inactive peptide sequence having a length of 1 to 10 amino acids. The amino acids of the spacer region are preferably selected from the group comprising glycine, ß-alanine, γ-aminobutyric acid, ∈-aminocaproic acid, lysine and compounds of the structural formula $NH_2[(CH_2)_nO]_x-CH_2-CH_2-COOH$ in which n is 2 or 3 and x equals 1 to 10. The spacer region is preferably a continuous sequence of amino acids at the amino terminus or/and carboxy terminus of the epitope region.

In an immunoassay according to the bridge test concept a first labelled antigen is used. All marker groups can be used for the method according to the invention e.g. radioactive and non-radioactive marker groups. The preferred non-radioactive marker groups can be directly or/and indirectly detectable. In the case of a directly detectable label the group generating a detectable measuring signal is located directly on the antigen. Examples of such direct signal-generating groups are chromogens (fluorescent or luminescent groups, dyes), enzymes, NMR-active groups or metal particles which are coupled in a known manner to a peptide or polypeptide antigen. The directly detectable marker group is preferably a metal chelate detectable by fluorescence or electrochemoluminescence and particularly preferably a ruthenium chelate, rhenium chelate, iridium chelate or osmium chelate, especially a ruthenium chelate, e.g. a ruthenium-(bis-pyridyl)$_3^{2+}$ chelate. Other suitable metal chelate marker groups are for example described in EP-A-0 580 979, WO 90/05301, WO 90/11511 and WO 92/14138. Reference is hereby made to these documents.

A further type of labelling which is suitable for the antigens according to the invention is an indirectly detectable label. In this type of labelling the antigen is coupled with an indirectly detectable group e.g. a biotin or hapten group which in turn can be detected by reaction with a suitable binding partner (streptavidin, avidin, or anti-hapten antibody) which in turn carries a signal-generating group. An organic molecule with a molecular weight of 100 to 2000 preferably of 150 to 1000 is preferably used as an indirect marker group in the form of a hapten.

The haptens are capable of binding to a specific receptor for the respective hapten. Examples of receptors are antibodies, antibody fragments that are directed against the hapten or another specific binding partner for the hapten such as e.g. streptavidin or avidin if the hapten is biotin. The hapten is preferably selected from the group comprising sterols, bile acids, sexual hormones, corticoids, cardenolides, cardenolide-glycosides, bufadienolides, steroid-sapogenines and steroid alkaloids. The hapten is particularly preferably selected from the group comprising cardenolides and cardenolide-glycosides. Representatives of these substance classes are digoxigenin, digitoxigenin, gitoxigenin, strophanthidin, digoxin, digitoxin, ditoxin and strophanthin, digoxigenin and digoxin being particularly preferred. Another suitable hapten is for example fluorescein or a suitable fluorescein derivative.

The receptor for the hapten is coupled to a signal-generating group, preferably to an enzyme such as peroxidase, alkaline phosphatase, ß-galactosidase, urease or Q-ß-replicase. However, the signal-generating

group can also be a chromogenic, radioactive or NMR-active group or a metal particle (e.g. gold). The hapten can for example be coupled to the antigen by coupling the hapten in the form of an active ester derivative to the amino terminus or/and to free amino side groups of the peptide or polypeptide antigen.

The term "active ester" within the sense of the present invention encompasses activated ester groups that can react with free amino groups of peptides under such conditions that no interfering side reactions with other reactive groups of the peptide can occur. An N-hydroxy-succinimide ester is preferably used as the active ester derivative. Examples of suitable hapten-active ester derivatives are digoxin-4'''-hemiglutarate-N-hydroxy-succinimide ester, digoxigenin-3-carboxymethyl ether-N-hydroxysuccinimide ester, digoxigenin-3-O-methyl-carbonyl-ε-aminocaproic acid-N-hydroxysuccinimide ester, digoxigenin-3-hemisuccinate-N-hydroxysuccinimide ester, digitoxin-4'''-hemiglutarate-N-hydroxysuccinimide ester and digitoxigenin-3-hemisuccinate-N-hydroxysuccinimide ester. These hapten derivatives are commercially available from the Boehringer Mannheim Company GmbH (Mannheim, GER). In addition to the N-hydroxysuccinimide esters it is also possible to use analogous p-nitro-phenyl, pentafluorophenyl, imidazolyl or N-hydroxybenzo-triazolyl esters.

In addition to the first labelled antigen a second antigen is also used in the method according to the invention which is bound to a solid phase or is present in a form capable of binding to a solid phase and can also be a multimeric antigen. Binding between the solid phase antigen and the solid phase can be covalent or adsorptive and occur directly, via chemical linker

groups or via a specific interaction e.g. biotin - streptavidin/avidin, antigen - antibody, carbohydrate - lectin. The solid phase antigen is preferably a biotinylated antigen and the solid phase is correspondingly coated with streptavidin or avidin. Biotin groups can be coupled to the antigen in a known manner e.g. by introduction of biotin active ester derivatives. Such methods are known to a person skilled in the art.

The number of marker or solid phase binding groups on the multimeric antigen is variable i.e. one or several groups may be present. In some embodiments of the method according to the invention it is preferable if at least 3 and particularly preferably 3 to 20 marker or solid phase binding groups are present. In this manner it is possible to achieve a surprisingly high improvement in sensitivity and a significant decrease in the Hook effect (false negative evaluation of strongly positive samples).

The present invention is based on the finding that in an immunological test for the determination of a specific antibody in a sample liquid it is advantageous if at least one of the two antigens used for the test is a multimeric antigen i.e. comprises several epitope regions preferably several identical epitope regions. The term "epitope region" in the sense of the present invention denotes a structure, preferably a peptide or polypeptide sequence, which exhibits a specific reaction with the antibody to be determined. There are several possibilities of arranging several epitope regions on the multiple antigen.

In a first embodiment a carrier which does not react with the antibody to be determined to which the epitope regions are covalently coupled is used as the multimeric antigen. Examples of suitable carriers are peptides, polypeptides or synthetic carriers e.g. dextrans. Examples of suitable polypeptides are albumins, e.g. bovine serum albumin, unspecific immunoglobulins, immunoglobulin fragments, ß-galactosidase and polylysine. If a carrier is used care must be taken that it exhibits no cross-reactivity with antibodies in the sample liquid.

The epitope regions are preferably coupled via a bifunctional linker to reactive groups of the carrier e.g. NH_2 groups or SH groups. The coupling is preferably achieved via NH_2 groups of the carrier.

In this embodiment of the invention an antigen of the general formula

$$(P\text{-})_nT(\text{-}L)_m \quad \text{(Ia)} \qquad \text{or} \qquad T(\text{-}P\text{-}L_m)_n \quad \text{(Ib)}$$

is preferably used in which T denotes a carrier, P denotes peptide or polypeptide sequences which contain identical or different immunologically reactive epitope regions and are covalently coupled to the carrier and L denotes marker groups or groups capable of binding to a solid phase which are covalently coupled to the carrier or to the peptide or peptide sequences, n is a number larger than 1 to 40 and m is a number between 1 and 10. The symbols n and m do not have to denote integers since the coverage of the carrier with epitope groups or with marker or solid phase binding groups can be statistical in a reaction mixture. n is preferably larger than or

equal to 2.

The peptide or polypeptide sequences coupled to the carrier preferably contain synthetic peptide sequences with a length of 6 to 50 amino acids or recombinant polypeptide sequences with a length of preferably up to 1000 amino acids.

Synthetic peptide sequences can in addition to the actual epitope region also optionally contain a spacer region as defined above which can for example be located between the epitope and carrier or/and between the epitope and marker or solid phase binding group.

The peptide or polypeptide epitopes can be coupled to the carrier via the N-terminus, the C-terminus or via reactive groups in the side chain. One method of coupling is to activate an NH_2 group of the carrier molecule by reaction with known linker substances (e.g. maleinimidohexanoic acid, maleinimidopropionic acid, maleinimidobenzoic acid) and covalently couple an SH-activated peptide derivative to the carrier. The marker or solid phase binding groups are usually coupled to the carrier molecule or/and to the epitope regions in the form of active esters. However, other coupling methods are also conceivable e.g. via bifunctional photolinkers.

In order to synthesize multimeric antigens which contain the epitopes coupled to an inert carrier, the appropriate peptides are preferably synthesised with a reactive mercapto group e.g. by introducing an additional cysteine residue. In this case the peptide can be modified with a linker either N-terminally, C-terminally or also at any position in the sequence. For

the reaction to form the multimeric antigen a carrier which contains primary amino groups can for example firstly be loaded with the appropriate active ester derivative of the marker group and subsequently with maleinimidoalkyl groups. In this manner the amino groups of the ϵ-amino side chain of lysine residues in the carrier are partially labelled with the marker group (e.g. digoxigenin or bipyridylruthenium) or the solid phase binding group (e.g. biotin) and the other portion is converted into maleinimide groups.

In a further step the peptide or the peptide mixture containing the desired epitope regions is then coupled to the maleinimide-modified carrier via the reactive mercapto function. If the marker group is located directly on the peptide, the multimeric antigen is synthesized in an analogous manner except that now an appropriately labelled SH-activated peptide is reacted with the carrier.

In a further embodiment of the invention a multimeric antigen can be used which contains several epitope regions which are covalently coupled together either directly or via spacer regions. The linking of the epitopes is preferably achieved at least partially via trifunctional linker molecules so that the antigen contains at least one branching site and preferably 1 to 7 branching sites.

In this embodiment an antigen of the general formula II is preferably used:

$$P^1\{P^2[P^3(P^4)_t]_s\}_r \qquad \text{(II)}$$

in which P^1, P^2, P^3 and P^4 denote peptide sequences with a length of up to 50 amino acids in which at least 2 peptide sequences contain identical or different immunologically reactive epitope regions, r is 1 or 2, s is an integer from 0 to 4 and t is an integer from 0 to 8 wherein the antigen contains at least one branching site and at least one marker group or a group capable of binding to a solid phase.

The antigen of formula II forms a tree-like structure with a maximum of 7 branching sites if P^1, P^2, P^3 and P^4 are linear peptide sequences and preferably contains two to eight identical or different immunologically reactive epitope regions. The epitope regions are preferably not linked directly together but via spacer regions. The spacer regions are preferably immunologically inactive peptide sequences with a length of 1 to 10 amino acids as defined above. Not all peptide sequences P^1, P^2, P^3 and P^4 have to contain epitope regions, instead structures are also possible in which these sequences only consist of spacer regions. Branches can be incorporated into the structure by using trifunctional amino acids e.g. lysine or ornithine.

In addition the antigen of the general formula II contains at least one marker or solid phase binding group as defined above. These groups can for example be coupled selectively to the ends or/and to reactive side chains of the peptide sequences.

So-called mosaic proteins are yet a further embodiment of multimeric antigens i.e. recombinant fusion polypeptides whose amino acid sequence contains several immunologically reactive epitope regions which are

optionally linked via immunologically inactive spacer regions. The recombinant mosaic proteins are obtainable by synthesizing a DNA sequence coding for the desired protein and expressing it in a recombinant host cell. Such procedures are known to a person skilled in the area of molecular biology and are described in standard textbooks (e.g. Sambrook et al., Molecular Cloning. A Laboratory Manual, 2nd Edition (1989), Cold Spring Harbor Laboratory Press). Marker or solid phase binding groups can also be introduced into the recombinant protein according to known methods.

In a further preferred embodiment of the invention the epitope regions are synthetic peptide sequences with a length of 6 to a maximum of 50 particularly preferably up to a maximum of 30 amino acids. Marker groups or solid phase binding groups can be selectively introduced into such epitope regions with regard to their location as well as with regard to their number. Thus in the synthetic production by using certain protecting groups on reactive side groups e.g. primary amino groups of the amino acid derivatives used it is possible to specifically select those positions of the peptide which are available for reaction with the introduced marker group after selective cleavage of the protecting group.

For this the peptide having the desired amino acid sequence is synthesized on a solid phase preferably using a commercial peptide synthesizer (e.g. the instruments A 431 or A 433 from Applied Biosystems). The synthesis is carried out according to known methods preferably starting at the carboxyl terminus of the peptide using amino acid derivatives. Amino acid derivatives are preferably used whose amino terminal groups required for coupling are derivatized with a

fluorenylmethyloxycarbonyl (Fmoc) residue. Reactive side groups of the amino acids used contain protecting groups that can be readily cleaved off after completion of the peptide synthesis. Preferred examples of this are protecting groups such as triphenylmethyl (Trt), t-butyl ether (tBu), t-butyl ester (0 tBu), tert.-butoxycarbonyl (Boc) or 2,2,5,7,8-pentamethylchroman-6-sulfonyl (Pmc).

The amino side chains of lysine residues or of other amino acid derivatives with primary amino side groups that are located at positions of the peptide which are later intended to be derivatized with the hapten are provided with a first amino protecting group which is selected such that it can be quantitatively cleaved off under particular reaction conditions e.g. in the presence of acid. An example of a suitable acid-labile protecting group is Boc. The side groups of lysine residues or of other amino acid residues with primary amino side groups to which no coupling of a hapten is desired are provided with a second amino-protecting group which is selected such that it cannot itself be cleaved off under conditions under which the first protecting group can be cleaved off. The second protecting group is also preferably stable under those conditions under which the peptide is cleaved from the solid phase and under which all other protecting groups are cleaved off. Examples of such second protecting groups are acid-resistant protecting groups such as phenylacetyl. In addition to the 20 natural amino acids the peptide can also contain artificial amino acids such as ß-alanine, γ-amino-butyric acid, ∈-amino-caproic acid or norleucine. These artificial amino acids are used for the synthesis in a protected form analogously to the natural amino acids.

After completion of the synthesis protecting groups, including the first amino-protecting groups, which are located at the positions at which the coupling of the hapten is to take place are cleaved, optionally after releasing the peptide from the solid phase. Then the product obtained in this manner is purified, preferably by HPLC. Subsequently the hapten label is introduced by reacting the peptide with the hapten-active ester derivative desired in each case which reacts with free primary amino groups i.e. with the amino terminal group or/and amino side groups of the peptide. Preferably 1.5 to 2.5 equivalents of active ester are used per free primary amino group. Subsequently the reaction product is purified, preferably by HPLC.

If the peptide still contains amino groups that are derivatized with a second protecting group such as phenylacetyl then these protecting groups are removed in the last step. Phenylacetyl protecting groups can for example be enzymatically removed at room temperature with immobilized or soluble penicillin G amidase in aqueous solution containing an organic solvent.

If the peptides produced by the process according to the invention contain an intramolecular disulfide bridge, then the peptide sequence can be oxidized on the solid phase with for example iodine in hexafluoroisopropanol/ dichloromethane (Cober et al. The Peptide, Academic Press, New York, 1981, pages 145 to 147) after completion of the synthesis but before cleaving the N-terminal Fmoc-protecting group of the last amino acid, and subsequently the N-terminal Fmoc-protecting group is cleaved.

A reactive SH group can for example be introduced by coupling a cysteine residue to the amino terminus of the peptide.

Metal chelate marker groups are introduced into synthetic peptides (a) after synthesis of the desired peptide sequence and preferably before cleavage of the peptide from the solid phase and before cleavage of protecting groups to reactive side groups of the amino acid derivatives used for the peptide synthesis by coupling an activated luminescent metal chelate e.g. an active ester derivative to the N-terminal primary amino group of the peptide and/or (b) during the synthesis of the peptide by introducing amino acid derivatives which are coupled covalently to a luminescent metal chelate marker group e.g. by means of a ∈-derivatized lysine.

Branched multimeric antigens can be synthesized by using a diaminocarboxylic acid such as lysine protected by two Fmoc groups. The peptides can for example be biotinylated by introducing a biotin derivative at the N-terminus while the peptide is still coupled to the solid phase.

Peptide epitopes or polypeptide epitopes from pathogenic organisms e.g. bacteria, viruses and protozoa or from autoimmune antigens are preferably used for the method according to the invention. The immunologically reactive epitope region is preferably derived from viral antigens e.g. the amino acid sequences of HIV I, HIV II, HIV subtype O or hepatitis C-virus (HCV).

Preferably HIV I or HIV II or subtype O epitopes are selected from the regions gp32, gp41, gp120 and gp24.

HCV epitopes are preferably selected from the Core/Env region or the non-structural protein regions NS3, NS4 or NS5.

The epitope region of HIV I or HIV II or HIV subtype O amino acid sequences is particularly preferably selected from the group of amino acid sequences:

NNTRKSISIG	PGRAFYT		(I)
NTTRSISIGP	GRAFYT		(II)
IDIQEERRMR	IGPGMAWYS		(III)
QARILAVERY	LKDQQLLGIW	GASG	(IV)
LGIWGCSGKL	ICTTAVPWNA	SWS	(V)
KDQQLLGIWG	SSGKL		(VI)
ALETLLQNQQ	LLSLW		(VII)
LSLWGCKGKL	VCYTS		(VIII)
WGIRQLRARL	LALETLLQN		(IX) and
QAQLNSWGCA	FRQVCHTTVP	WPNDSLT	(X)

or partial sequences thereof which have a length of at least 6 and preferably of at least 8 amino acids.

The amino acid sequences I to III are derived from the gp120 region of HIV I, the amino acid sequences IV to IX are derived from the gp41 region of HIV I and the amino acid sequence X is derived from the gp32 region of HIV II. The amino acid sequences I to X are also shown in the sequence protocols SEQ ID NO. 1 to SEQ ID NO. 10. Each of the sequences V, VIII and X contain two cysteine residues which are preferably present in the form of a disulfide bridge.

The epitope region of HCV amino acid sequences is preferably selected from the group of the amino acid sequences:

SRRFAQALPV	WARPD		(XI)
PQDVKFPGGG	QIVGGV		(XII)
EEASQHLPYI	EQ		(XIII)
QKALGLLQT			(XIV)
SRGNHVSPTH	YVPESDAA		(XV)
PQRKNKRNTN	RRPQDVKFPG		
GGQIVGVV			(XVI) and
AWYELTPAET	TVRLRAYMNT	PGLPV	(XVII)

or partial sequences thereof which have a length of at least 6 and preferably at least 8 amino acids. The sequence XI is derived from the NS5 region, the sequences XII and XVI from the Core region, the sequences XIII, XIV and XV from the NS4 region and the sequence XVII is derived from the NS3 region of HCV. The amino acid sequences XI to XVII are also shown in the sequence protocols SEQ ID NO. 11 to SEQ ID NO. 17.

The present invention in addition concerns a reagent for the immunological determination of a specific antibody in a sample liquid comprising a reactive phase, two antigens directed against the antibody to be determined of which the first antigen carries a marker group and the second antigen is (a) bound to the solid phase or (b) is present in a form capable of binding to the solid phase characterized in that at least one of the two antigens contains several epitope regions which react to the antibody to be determined.

In one embodiment of the present invention the reagent contains a first labelled antigen with several epitope regions which carries at least one hapten marker group and a receptor for the hapten which in turn contains a signal-generating group. In addition a reagent is

preferred which comprises a second solid phase antigen with several epitope regions which carries at least one biotin group and a reactive solid phase coated with streptavidin or avidin.

Yet a further subject matter of the present invention is the use of multimeric antigens which contains several immunologically reactive epitope regions in an immunological test procedure to determine specific antibodies in a sample liquid.

Those antibodies are preferably determined which indicate an infection by microorganisms such as bacteria, viruses or protozoa. Antibodies directed against viruses such as e.g. against HIV or hepatitis viruses are particularly preferably determined. The sample liquid is preferably serum, particularly preferably human serum. In addition it is preferred that the multimeric antigens according to the invention are used in an immunological method in a bridge test format.

The test procedure preferably comprises mixing the sample liquid with the first antigen and the second antigen on the solid phase in order to obtain a labelled immobilized complex of first antigen, antibody and solid phase-bound second antigen. Compared to other test formats for detecting antibodies, the bridge test format leads to an improvement in sensitivity i.e. all immunoglobulin classes such as IgG, IgM, IgA and IgE are recognized as well as in specificity i.e. the unspecific reactivity is reduced. The specificity and sensitivity of the double antigen bridge test can be further improved if a two step test procedure is used in which the sample liquid is mixed with the first and the second

antigen in a first step and subsequently the receptor for the hapten label of the first antigen which carries the signal-generating group is added after 1 to 4 h, particularly preferably after 1.5 to 2.5 h.

The invention finally also concerns new antigens of formulae (Ia), (Ib) and (II) as defined above.

The present invention is further described by the following examples, sequence protocols and figures.

SEQ ID NO. 1: shows the amino acid sequence of an epitope from the gp120 region of HIV I;
SEQ ID NO. 2: shows the amino acid sequence of a further epitope from the gp120 region of HIV I;
SEQ ID NO. 3: shows the amino acid sequence of a further epitope from the gp120 region of HIV I, subtype O;
SEQ ID NO. 4: shows the amino acid sequence of an epitope from the gp41 region of HIV I;
SEQ ID NO. 5: shows the amino acid sequence of a further epitope from the gp41 region of HIV I;
SEQ ID NO. 6: shows the amino acid sequence of yet a further epitope from the gp41 region of HIV I;
SEQ ID NO. 7: shows the amino acid sequence of an epitope from the gp41 region of HIV I, subtype O;
SEQ ID NO. 8: shows the amino acid sequence of a further epitope from the gp41 region of HIV I, subtype O;
SEQ ID NO. 9: shows the amino acid sequence of yet a further epitope from the gp41 region of HIV I, subtype O;
SEQ ID NO.10: shows the amino acid sequence of an epitope from the gp32 region of HIV II;

SEQ ID NO.11: shows the amino acid sequence of an epitope from the NS5 region of HCV;
SEQ ID NO.12: shows the amino acid sequence of an epitope from the Core region of HCV;
SEQ ID NO.13: shows the amino acid sequence of an epitope from the NS4 region of HCV;
SEQ ID NO.14: shows the amino acid sequence of a further epitope from the NS4 region of HCV;
SEQ ID NO.15: shows the amino acid sequence of yet a further epitope from the NS4 region of HCV;
SEQ ID NO.16: shows the amino acid sequence of a further epitope from the Core region of HCV and
SEQ ID NO.17: shows the amino acid sequence of an epitope from the NS3 region of HCV;
Figure 1: shows the amino acid sequence of the recombinant HIV p24 antigen,
Figure 2: shows a comparison of the measured signals in a double antigen bridge test when using a monomeric and a multimeric ruthenylated HIV-gp120 antigen and
Figure 3: shows a comparison of the measured signals in a double antigen bridge test when using a monomeric and a multimeric biotinylated HIV-gp41 antigen.

Example 1

Synthesis of peptide epitope regions

The peptide epitope regions were synthesized by means of fluorenylmethyloxycarbonyl (Fmoc) solid phase peptide synthesis on a batch peptide synthesizer e.g. from Applied Biosystems A431 or A433. For this 4.0 equivalents of each of the amino acid derivatives shown

in table 1 were used:

Table 1

A	Fmoc-Ala-OH
C	Fmoc-Cys(Trt)-OH
D	Fmoc-Asp(tBu)-OH
E	Fmoc-Glu(tBu)-OH
F	Fmoc-Phe-OH
G	Fmoc-Gly-OH
H	Fmoc-His(Trt)-OH
I	Fmoc-Ile-OH
K1	Fmoc-Lys(phenylacetyl)-OH
K2	Fmoc-Lys(Boc)-OH
K3	Fmoc-Lys(Fmoc)-OH
K4	Fmoc-Lys(BPRu)-OH
L	Fmoc-Leu-OH
M	Fmoc-Met-OH
N	Fmoc-Asn(Trt)-OH
P	Fmoc-Pro-OH
Q	Fmoc-Gln(Trt)-OH
R	Fmoc-Arg(Pmc)-OH
S	Fmoc-Ser(tBu)-OH
T	Fmoc-Thr(tBu)-OH
U	Fmoc-ßAlanine-OH
V	Fmoc-Val-OH
W	Fmoc-Trp-OH
Y	Fmoc-Tyr(tBu)-OH
Z	Fmoc-ϵ-aminocaproic acid-OH
Nle	Fmoc-ϵ-norleucine-OH
Abu	Fmoc-γ-aminobutyric acid-OH

If cysteine residues are present in the peptide

sequence, an oxidation on the solid phase is carried out immediately after completion of the synthesis using iodine in hexafluoroisopropanol/dichloromethane.

The amino acids or amino acid derivatives were dissolved in N-methylpyrrolidone. The peptide was synthesized on 400-500 mg 4-(2',4'-dimethoxyphenyl-Fmoc-aminomethyl)-phenoxy resin (Tetrahedron Letters 28 (1987), 2107) with a loading of 0.4-0.7 mmol/g (JACS 95 (1973), 1328). The coupling reactions were carried out for 20 minutes in dimethylformamide as the reaction medium with 4 equivalents dicyclohexylcarbodiimide and 4 equivalents N-hydroxybenzotriazol relative to the Fmoc-amino acid derivative. The Fmoc group was cleaved within 20 minutes after each synthesis step using 20 % piperidine in dimethylformamide.

The release of the peptide from the synthesis resin and the cleavage of the acid-labile protecting groups - with the exception of the phenylacetyl protecting group - was achieved within 40 min at room temperature with 20 ml trifluoro acetic acid, 0.5 ml ethanedithiol, 1 ml thioanisol, 1.5 g phenol and 1 ml water. The reaction solution was subsequently admixed with 300 ml cooled diisopropyl ether and kept at 0°C for 40 min to completely precipitate the peptide. The precipitate was filtered, washed again with diisopropyl ether, dissolved in a small amount of 50 % acetic acid and lyophilized. The crude material obtained was purified for ca. 120 min. by means of preparative HPLC on delta-PAK RP C18 material (column 50 x 300 mm, 100 Å, 15 μ) using an appropriate gradient (eluant A: water, 0.1 % trifluoro-acetic acid, eluant B: acetonitrile, 0.1 % trifluoro-acetic acid). The identity of the eluted material was checked by means of ion spray mass spectrometry.

The hapten label, e.g. a digoxigenin or digoxin label, was introduced in solution by coupling appropriate active ester derivatives e.g. digoxigenin-3-carboxy-methylether-N-hydroxysuccinimide ester (Boehringer Mannheim GmbH, Mannheim, GER) to the free amino groups of the peptide. The peptide to be derivatized was dissolved in a mixture of DMSO and 0.1 M potassium phosphate buffer pH 8.5. Subsequently 2 equivalents of active ester per free primary amino function dissolved in a small amount of DMSO was added dropwise and stirred at room temperature. The reaction was monitored by means of analytical HPLC. The product is purified by means of preparative HPLC.

The lysine derivative K1 was used for positions at which no hapten labelling was to take place. The lysine derivative K2 was used for positions at which a hapten labelling was to take place. The lysine derivative K3 was used to couple the ϵ-amino group to the peptide in the spacer region.

If the peptide still contained lysines protected with phenylacetyl, then this protecting group was enzymatically cleaved at room temperature in the last step using penicillin G amidase in an aqueous medium containing a proportion of organic solvent. The enzyme was filtered and the peptide was purified by means of preparative HPLC. The identity of the eluted material was checked by means of ion spray mass spectrometry.

A ruthenium marker group was introduced either N-terminally by means of a ruthenium(bispyridyl)$_3$-carboxylic acid derivative (BPRu-COOH), e.g. Ru-(bispyridyl)$_3^{2+}$-N-hydroxysuccinimide ester or into the

sequence by means of an ∈-derivatized lysine residue K4 (Fmoc-Lys(BPRu)OH).

A biotin label was introduced either N-terminally by derivatization on a resin (biotin active ester) or within the sequence analogously to the introduction of a ruthenium label by means of a lysine appropriately ∈-derivatized with biotin.

Branched multimeric peptides were synthesized analogously to the synthesis of the linear peptides. In this case a resin with a low loading density e.g. with a loading of 0.2 mmol/g was selected as the solid phase. A bis Fmoc-protected diamino carboxylic acid such as Fmoc-Lys(Fmoc)-OH was used for the branching.

The prepared peptides are listed in Tables 2 and 3.

The peptide compounds shown in Tables 2a-2d were prepared from the regions gp120, gp41 and gp32 of HIV I and HIV II.

Table 2a: SH-activated linear peptides

gp41/1	CUZU-WGIRQLRARLLALETLLQN
gp41/2	CUZU-LSLWGCKGKLVCYTS
gp41/4	CUZU-ALETLLQNQLLSLW
gp120	CUZU-IDIQEMRIGPMAWYS

Table 2b: Digoxigenin-labelled linear peptides

gp120	digoxigenin-3-cme-UZU-NNTRKSISIGPGRAFYT digoxigenin-3-cme-UZ-NTTRSISIGPGRAFY digoxigenin-3-cme-UZU-IDIQEERRMRIGPGMAWYS
gp41/1	digoxigenin-3-cme-UZU-AVERYLKDQQLLGIW digoxigenin-3-cme-ZUZU-AVERYLKDQQLLGIW digoxigenin-3-cme-UZ-QARILAVERYLKDQQLLGIWGASG digoxigenin-3-cme-ZGGGG-QARILAVERYLKDQQLLGIWGASG digoxigenin-3-cme-UZU-WGIRQLRARLLALETLLQN
gp41/2	digoxigenin-3-cme-UZU-LGIWGCSGKLICTTAV LGIWGCSGK-(cme-3-digoxigenin)-LICTTAV digoxigenin-3-cme-UZU-LGIWGCSGK-(cme-3- digoxigenin)-LICTTAV digoxigenin-3-cme-ZU-GCSGKLICTTAVPWNASWS GCSGK-(cme-3-digoxigenin)-LICTTAVPWNASWS GCSGKLICTTAVPWNASWSK(cme-3-digoxigenin)G digoxigenin-3-cme-UZU-LSLWGCKGKLVCYTS
gp41/3	digoxigenin-3-cme-UZU-KDQQLLGIWGSSGKL
gp41/4	digoxigenin-3-cme-UZU-ALETLLQNQLLSLW
gp32	digoxigenin-3-cme-Z-NSWGCAFRQVCHTT

Table 2c: Ruthenylated linear peptides

gp120	BPRu-UZU-NNTRKSISIGPGRAFYT BPRu-UZ-NTTRSISIGRGRAFY BPRu(ethyleneglycol)-UZ-NTTRSISIGPGRAFY PBRu-UZU-IDIQEERRMRIGPGMAWYS
gp41/1	PBRu-UZU-AVERYLKDQQLLGIW BPRu-UGGG-QARILAVERYLKDQQLLGIWGASG BPRu-GGGG-QARILAVERYLKDQQLLGIWGASG BPRu-UZU-WGIRQLRARLLALETLLQN
gp41/2	BPRu-UZU-LGIWGCSGKLICTTAV BPRu-UGGG-GCSGKLICTTAVPWNASWS (GCSGKLICTTAVPWNASWS)K-(BPRu)
gp41/3	BPRu-UZU-KDQQLLGIWGSSGKL
gp41/4	BPRu-UZU-ALETLLQNALLSLW
gp32	BPRu-UZU-NSWGCAFRQVCHTT BPRu-GGG-QAQLNSWGCAFRQVCHTTVPWPNDSLT

Table 2d: Branched peptides

gp120	(NTTRSISIGPGRAFY-AbuZ AbuZ)$_2$-K-Z-AbuZ-K-(Bi) ((NTTRSISIGPGRAFY-ZU)$_2$-K-UU-K-(Bi) ((NNTRKSISIGPGRAFYT-UZU-K)$_2$-UZU- NNTRKSISIGPGRAFYT-UZU-K)$_2$-UZU-Bi
gp120	(NTTRSISIGPGRAFY-ZU)$_2$-K-UU-K-(BPRu)

The peptides shown in the following Tables 3a-d were synthesized from the NS5 region, the NS4 region, the Core region and the NS3 region of HCV.

Table 3a: SH-activated linear peptides

NS4/3	C-UZ-SRGNHVSPTHYVPESDAA

Table 3b: Hapten-labelled linear peptides

NS5/1	digoxigenin-3-cme-UZU-SRRFAQALPVWARPD
Core2m	digoxigenin-3-cme-U-PQDVKFPGGGQIVGGV
NS4/1	digoxigenin-3-cme-UU-Nle-EEASQHLPYIEQ
NS4/2	digoxigenin-3-cme-UU-QKALGLLQT
NS4/3	digoxigenin-3-cme-UZU-SRGNHVSPTHYVPESDAA
Core1	digoxigenin-3-cme-UZU-KNKRNTNRR
Core1+2	digoxigenin-3-cme-U-PQRKNKRNTNRRPQDVKFPGGGQIVGVV
NS3/1	digoxigenin-3-cme-UZ-AWYELTPAETTVRLRAYMNTPGLPV

Example 3c: Ruthenylated linear peptides

Core1	BPRu-GGGG-KNKRNTNRR
Core1+2	BPRu-UZU-KNKRNTNRRPQDVKFPGGGQIVGGV
NS4/1+2	BPRu-UZU-SQHLPYIEQG-NleNle-LAEQFKQQALGLLQT
NS4/3m	BPRu-UZ-SRGNHVSPTHYVPESDAA
NS5/1	BPRu-UZ-SRRFAQALPVWARPD
Core1+2+3	BPRz-UZ-KNKRNTNRRPQDVKFPGGGQIVGGVLLPRR
Core1m	BPRu-UZ-NPKPQKKNKRNTNRR
Core3m	BPRu-UZ-GQIVGGVYLLPRRGPRLG
Core2m	BPRu-UZ-PQDVKFPGGGQIVGGV
NS4/3m-I	BPRuz-UZU-SRGNHVSPTHYVPESDAA
NS4/1	BPRu-UZU-SQHLPYIEQ

Table 3d: Branched peptides

NS4/3m	$(SRGNHVSPTHYVPESDAA\text{-}UU)_2$ KUUK (BPRu) $(SRGNHVSPTHYVPESDAA\text{-}UU)_4$ K_2KUUK (BPRu) $(SRGNHVSPTHYVPESDAA\text{-}UU)_8$ $K_4U_4K_2$KUUK (BPRu) $(SRGNHVSPTHYVPESDAA\text{-}UU)_2$ KUUK (Z-Bi) $(SRGNHVSPTHYVPESDAA\text{-}UU)_4$ K_2KUUK (Z-Bi) $(SRGNHVSPTHYVPESDAA\text{-}UU)_8$ $K_4U_4K_2$ KUUK (Z-Bi)

Example 2

Synthesis of carrier-bound multimeric antigens (polyhaptens) with peptide epitopes

The appropriate peptides were synthesized with a reactive mercapto function e.g. by introducing an additional cysteine (cf. Tables 2a and 2b). In this process the peptide can be modified with a so-called linker either N-, or C-terminally or at any desired position in the sequence. The corresponding peptides were synthesized as described in example 1.

For the reaction to form the polyhapten the carrier containing NH_2 groups was firstly loaded with the appropriate active ester of the marker groups and subsequently with maleinimidoalkyl groups, preferably by treatment with maleinimidohexyl- (MHS) or maleinimidopropyl-N-hydroxysuccinimide ester (MPS). By this means the primary amino groups in the carrier (e.g. ϵ-amino side chain of lysine residues) were partially labelled and the other part was converted into maleinimide groups.

The carrier was preferably reacted with the active esters in 0.1 mol/l potassium phosphate buffer pH 7.0-8.5 within 2-4 h at room temperature using a concentration of 5-20 mg/ml. The lower molecular components were either separated by dialysis or gel chromatography (AcA 202-Gel, eluant 0.1 mol/l potassium phosphate buffer pH 7-8.5).

The peptide or the peptide mixture was then coupled within 6 h at room temperature in a further step with the reactive mercapto function on the MHS-modified labelled carrier in 0.1 mol/l potassium phosphate buffer pH 8.5. Non-reacted peptide was either separated by dialysis or gel chromatography.

If the label was to be located directly on the peptide, the polyhapten was synthesized analogously and an appropriately labelled SH-activated peptide was used.

Rabbit IgG, bovine serum albumin, ß-galactosidase, amino-dextran and bovine Fab antibody fragments were used as carriers. The loading of the carrier with the peptide sequences was 1:2 - 1:20 on a molar basis. The loading of the carrier with marker groups was 1:1 to 1:20 on a molar basis.

Example 3

Synthesis of carrier-bound multimeric antigens (polyhaptens) containing polypeptide epitopes as exemplified by poly-p24-BSA-BPRu

1. Principle

Bovine serum albumin (BSA) was reacted in the stated order with ruthenium-(bis-pyridyl)$_3^{2+}$-N-hydroxy-succinimide ester (BPRu) and maleinimidohexanoyl-N-hydroxysuccinimide ester (MHS) and dialysed in each case to separate the free, non-bound derivatization reagents.

Recombinant p24 antigen from E. coli (Ghrayeb and Chang, DNA5 (1986), 93-99) with the amino acid sequence shown in Figure 1 was reacted with N-succinimidyl-S-acetylthio propionate (SATP) to introduce thiol residues via amino groups and dialysed to separate free non-bound SATP.

After releasing the SH groups in the activated p24 antigen it was coupled to the maleinimido functions of BSA-BPRu. Excess functional coupling groups were captured with cysteine and N-methylmaleinimide and the reaction was thus terminated.

The product was then isolated from the reaction mixture by chromatography on Sephacryl S 200.

2.1 Synthesis of BSA (MH)-BPRu

A 5-fold molar excess of BPRU reagent (0.4 ml BPRU stock solution containing 47 mg/ml in DMSO) was added to 250 mg BSA at a protein concentration of 20 mg/ml in PBS buffer pH 8.0.

After the addition it was stirred for a further 75 min at 25°C. The reaction was then stopped by addition of lysine to a final concentration of 10 mmol/l and stirred

for a further 30 min at 25°C.

SH groups of BSA that are present were derivatized by addition of iodoacetamide to a final concentration of 10 mmol/l. For this purpose the mixture was stirred for a further 45 min at 25°C and pH 8.0.

Free non-bound derivatization reagents were completely separated by dialysis (20 hours, 4°C) against > 500-fold volume of PBS buffer pH 7.5 (50 mmol/l Na phosphate, 150 mmol/l NaCl, pH 7.5).

The incorporation of BPRU was 4.7 moles per mole BSA. The yield was 220 mg BSA-BPRU (89 %).

Then a 25-fold molar excess of MHS reagent (0.5 ml MHS stock solution containing 50 mg/ml in DMSO) was added to 220 mg BSA-BPRU at a protein concentration of 20 mg/ml in PBS buffer pH 7.1 and stirred for a further 60 min at 25°C.

The reaction was stopped by addition of lysine to a final concentration of 10 mmol/l and stirred for a further 30 min at 25°C.

Free non-bound MHS reagent was completely separated by dialysis (20 hours, 4°C) against > 500-fold volume PBS buffer pH 7.5. Yield: 210 mg BSA(MG)-BPRU (84 %).

2.2 Synthesis of p24 antigen (SATP)

A 3-fold molar excess of SATP reagent (0.06 ml SATP stock solution containing 35 mg/ml in DMSO) was added to

100 mg p24 antigen at a protein concentration of 10 mg/ml in 0.1 M Na phosphate, 0.1 % (w/v) SDS, pH 7.1 and it was stirred for a further 60 min at 25°C.

The reaction was then stopped by addition of lysine to a final concentration of 10 mmol/l and stirred for a further 30 min at 25°C.

Free non-bound SATP reagent was subsequently completely separated by dialysis (20 hours, room temperature) against > 500-fold volume 0.1 mol/l Na-phosphate, 0.1 % (w/v) SDS, pH 6.5.
Yield: 95 mg p24 antigen (SATP) (95 %).

2.3 Synthesis of poly-p24-antigen BSA-BPRU

Hydroxylamine (1 mol/l; Merck) was added to a final concentration of 30 mmol/l to 95 mg p24 antigen (SATP) at a protein concentration of 10 mg/ml in 0.1 mol/l Na-phosphate, 0.1 % (w/v) SDS, pH 7.5.

18 mg BSA(MH)-BPRU was added and the mixture was stirred for a further 60 min at a protein concentration of 9 mg/ml (pH 7.1; 25°C). In order to stop the reaction cysteine was added to a final concentration of 2 mmol/l and stirred for a further 30 min at pH 7.1. N-methyl-maleimide (Sigma) was subsequently added to a final concentration of 5 mmol/l and it was stirred for a further 30 min at pH 7.1 and 25°C.

The mixture stopped in this manner was dialysed for 18 hours at room temperature (RT) against > 500-fold volume 0.1 mol/ Na-phosphate, 0.1 % (w/v) SDS, pH 6.5 and

purified over a Sephacryl S 200 column (Pharmacia). The most important general conditions for the column operation are: column volume 340 ml, application volume 12 ml, flow rate: 13.0 cm/hour, mobile buffer 0.1 mol/l Na-phosphate, 0.1 % (w/v) SDS, pH 6.5, operating temperature RT.

The column operation was monitored at a wavelength of 280 nm by means of a flow-through photometer and collected in fractions (fraction size about 0.5 % of the column volume).

After UV recording the fractions of the high molecular elution profile were collected into a pool, the product was concentrated in an Amicon stirred cell with a YM30 membrane (Amicon) to a protein concentration of 10 mg/ml and frozen at -80°C.

Incorporation: 5 mole p24 antigen per mole p24 antigen-BSA-BPRU. Yield: 19 mg.

Example 4

Improvement of the sensitivity of the bridge test format by using multimeric antigens

a) Carrier-bound multimeric antigens (polyhaptens)

Various variants of biotinylated polyhaptens were used in a double-antigen immunoassay in combination with a monomeric digoxygenylated hapten and namely with the same molar amount of biotinylated or digoxigenylated hapten. The amino acid sequence NNTRKSISIGPGRAFYT from

the gp120 region of HIV was used as the epitope. The haptens were synthesized as described in examples 1 and 2. The relative reactivity of native anti-HIV sera with the various biotinylated polyhaptens was standardized to the reactivity of sera with the corresponding biotinylated monomeric hapten (= 100 % reactivity).

The results of this experiment are shown in Table 4.

Carrier molecule	Effective loading per carrier molecule		Reactivity: compared to monomeric antigen (= 100 %)
	biotin	peptide	
BSA (MW:69000)	1	4.2	ca. 173.0 %
(ca. 627 Aa)	1	**5.1**	**ca. 185.0 %**
ß-Gal (MW: 465000)	1	2.2	ca. 123.5 %
(ca. 4227 Aa)	1	**3.6**	**ca. 151.8 %**
	1	9.4	ca. 125.0 %
Bovine-Fab (MW:75000)	1	5.9	ca. 146.0 %
(ca. 682 Aa)			

b) Multimeric branched antigens

Biotinylated and ruthenylated antigens with monomeric or multimeric branched epitopes were compared in a double antigen immunoassay in a bridge test format.

In the case of one epitope from the NS4 region of HCV (sequence SRGNHVSPTHYVPESDAA) the combination of a monomeric biotinylated antigen and a monomeric ruthenylated antigen was compared with the combination of multimeric branched biotinylated antigen (see Table 3d, line 2) and a monomeric ruthenylated antigen in a

bridge test. The signal differentiation was determined i.e. the ratio in the measured signal between positive and negative samples. A higher signal differentiation means a better sensitivity. When using a multimeric biotinylated antigen a signal differentiation of 386 compared to a signal differentiation of only 208 for the combination of both monomeric antigens was obtained.

A double antigen bridge test was carried out correspondingly using an antigen sequence from the gp120 region of HIV. The epitope used has the amino acid sequence NTTRSISIGPGRAFY. A combination of a monomeric biotinylated and a monomeric ruthenylated antigen was compared with a combination of a multimeric branched biotinylated antigen (see Table 2d, line 2) and a multimeric ruthenylated antigen (see Table 2d, line 4). In a test using the combination of the two multimeric antigens a signal differentiation between a positive and negative sample of 12 was found. In contrast the combination of both monomeric antigens only has a signal differentiation of 10.

Example 5

Improvement of the sensitivity of the bridge test format by using multimeric carrier-bound antigens

A combination of a monomeric biotinylated and a monomeric ruthenylated antigen, was examined in a bridge test together with a combination of a monomeric biotinylated antigen and a carrier-bound multimeric ruthenylated antigen (carrier molecule: bovine serum albumin; epitope: HIV-p24 antigen; produced according to example 3) and a combination of carrier-bound multimeric

biotinylated antigen and a monomeric ruthenylated antigen. In two different positive samples (HIV sera) a signal differentiation positive/negative of 2 was found in each case with the combination of the two monomeric antigens whereas the combination of a monomeric biotinylated antigen and a multimeric ruthenylated antigen yielded a differentiation of 19 and 7 and the combination of the multimeric biotinylated antigen and a monomeric ruthenylated antigen yielded a differentiation of 4 and 3.

Even when using a combination of a monomeric biotinylated antigen and another multimeric ruthenylated antigen (carrier molecule: rabbit immunoglobulin) a much larger signal differentiation of positive/negative of 3, 22 and 10 was found in three different positive samples compared to 2, 9 and 8 for a combination of the monomeric antigens.

Even when using another epitope (recombinant protein from the HIV-gp41 region) it was possible to demonstrate the superiority of the multimeric antigens compared to the monomeric antigens. Whereas in the case of a combination of monomeric biotinylated and digoxigenylated antigens practically no differentiation between negative and positive was found in the bridge test, the combination of multimeric polyhaptens showed a very good differentiation.

Example 6

Improvement of the sensitivity of the bridge test format by using multimeric antigens

A combination of an immobilized monomeric antigen and a labelled multimeric antigen is particularly preferred to achieve an optimal sensitivity over a broad concentration range of specific immunoglobulin. The preferred amounts used are 1 equivalent immobilized epitope to 0.2 - 10 and in particular 0.2 - 8 equivalents labelled epitopes.

Figure 2 shows a comparison of a combination of a monomeric biotinylated antigen and a monomeric ruthenylated antigen in an epitope ratio of 1:1 (curve 1) and a combination of a monomeric biotinylated antigen and a multimeric ruthenylated carrier-bound antigen in an epitope ratio of 1:2 (curve 2) and 1:4 (curve 3).

The sequence stated in example 4a from the gp120 region of HIV was used as the epitope. The carrier molecule for the multimeric antigen was BSA. The loading of the carrier with epitope groups was 5:1 and 3:1 with the BPRu groups, each on a molar basis.

It is apparent from figure 2 that the use of multimeric antigens leads to a reduction of the Hook effect and to a general increase in the sensitivity.

Example 7

Improvement of the sensitivity of the bridge test format when using multimeric antigens by increasing the number of marker groups.

A further improvement of test sensitivity is achieved due to the fact that it is possible to increase the number of marker and solid phase binding groups to a large extent without masking the epitope regions or increasing the unspecific background values by increasing the hydrophobicity.

Digoxigenylated multimeric antigens were compared which contained epitopes from the gp120 region of HIV (cf example 4b) coupled to a bovine Fab antibody fragment carrier. In each case the carrier was loaded with the peptide epitope in the range of 1:6 to 1:7 on a molar basis. The loading of the carrier with digoxigenin groups was 1:2 and 1:4.

The results of this experiment are shown in Table 5. It can be seen that a non-linear improvement in sensitivity and a considerable reduction in the Hook effect was achieved by increasing the number of marker groups.

Table 5

Sample	Stoichiometry carrier: Dig. 1:4	Stoichiometry carrier: Dig. 1:2
Dynamics of the measuring range Dilution steps	mA	mA
1/16384	36	148
1/8192	48	159
1/4096	49	151
1/2048	82	158
1/1024	132	159
1/512	302	157
1/256	675	164
1/128	1503	190
1/64	3493	259
1/32	7436	480
1/16	9303	1066
1/8	9449	3036
1/4	9449	3378
1/2	9449	2694
undiluted	9474	2266

Example 8

Improvement of the stability by using multimeric antigens

The stability of monomeric and multimeric antigens was tested. For this purpose the signal recovery after a three day incubation at 35°C relative to the original signal intensity was determined.

A signal recovery of 3.0 and 4.0 % for two samples was determined for a monomeric ruthenylated antigen from the gp120 region of HIV (sequence see example 4) in combination with a fresh biotinylated monomeric antigen. When using a carrier-bound multimeric ruthenylated antigen (carrier: rabbit IgG, 4 marker groups and 3 epitopes per carrier molecule) a signal recovery of 73.1 and 73.6 % was determined under the same test conditions.

A biotinylated monomeric antigen with the same epitope sequence was examined in a similar manner together with a carrier-bound biotinylated multimeric antigen (carrier: rabbit IgG, 18 biotin groups and 3 epitopes per carrier) in combination with a monomeric ruthenylated antigen. Signal recoveries of 25.0 and 37.0 % were determined for the monomeric biotinylated antigen and 120.3 and 79.9 % for the multimeric antigen.

Example 9

Improvement of the sensitivity with respect to the reactivity with antigens of low affinity

Multimeric antigens are preferably used to detect specific immunoglobulins of low affinity e.g. in the case of a recent seroconversion and in the case of new viral subtypes.

a) Ruthenylated multimeric antigens

The positive/negative signal differentiation was examined using antigens with an epitope sequence from the NS4/3 region of HCV. A combination of a monomeric ruthenylated and a monomeric biotinylated antigen resulted in a positive/negative signal differentiation of 3 and 1 in two different positive seroconversion samples i.e. a positive sample was not recognized as such. When multimeric IgG carrier-bound biotinylated and ruthenylated antigens were used a signal differentiation of 21 was determined in each case. Only the use of multimeric antigens enables the positive samples to be correctly classified.

b) Biotinylated multimeric antigens

The same peptide epitope from the gp41 region of HIV (gp41/3) was compared in each case as a carrier-bound multimeric antigen and as a monomeric antigen. In each case 50 ng/ml biotinylated and digoxigenylated monomeric peptide was used. In the case of the multimeric antigens 50 ng/ml "peptide equivalent" was used in which the amount of peptide was calculated from the degree of loading of the polyhapten. The test was carried out on

an ES700 automated analyzer.

The test was carried out using various seroconversion panels as samples. Figure 3 shows that the panels were correctly classified as positive in tests using the digoxigenylated polyhapten whereas a false negative result was obtained when using the monomeric antigen. The cut-off index is the boundary between negative and positive evaluation of an experiment. It is defined as the double value of the negative control.